THE RELATION OF THE NERVOUS SYSTEM TO HEAT PRODUCTION.[1]

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IN the *Journal of Nervous Diseases* I have classified the centres concerned in heat regulation as thermotaxic, whether concerned with thermogensis, thermolysis, or thermo-inhibition. In some experiments just made with atropin it was found to act upon the cerebral thermotaxic centres and not on the spinal. It occurred to me that perhaps the heat was nearly all generated in the tissues. To determine this, it would be necessary to remove so much of the nervous system as possible and then determine the amount of heat produced. Cats were selected for this purpose. They were put into the calorimeter for two hours, when they were removed, etherized and portions of the spinal cord destroyed. The calorimeter employed was the one improved by me, and whose error is only 5.4 per cent. After the animal was under the ether, an opening was made into the vertebral canal in the upper dorsal region and the cord destroyed downward by means of a stiff wire as far as the lumbar vertebræ, where a second opening was made in the vertebra canal and the remainder of the cord destroyed. Then the animal was immediately returned to the calorimeter and the heat production studied for four more hours. After this he was killed with chloroform. It was found that sections below the fifth dorsal were nearly always followed by recovery. If above, near the last cervical vertebra, there was often arrest of the heart and death. It was found that after sections above the fifth dorsal that the heat production fell to nearly one or two units, but afterwards rose to about one-third to one-half of the normal output (Exp. 1). If, however, the section was just at the fifth dorsal, then nearly always the heat production remained but little below the normal amount (Exp. 2). In one case (Exp. 3) it exceeded the normal amount. Eleven experiments were made and they confirmed the preceeding statements. The inquiry now arises, how are they to be explained? It is known if you divide the spinal cord between the fifth and sixth dorsal nerves, that is, where the splanchnics fibres divide from the cord, then the blood vessels of the skin and of the abdomen dilate and the blood-pressure falls greatly. If the section is made above the level of the second dorsal nerve, then in addition to the above vaso-motor paralysis there is a dilation of the vessels of the face and head which still further reduces the arterial tension. The cardiac accelerator nerves also leave the spinal cord by the second and third dorsal nerves and possibly to some extent by the fourth and fifth. While the vaso-constructor centres of the body are in the dorsal cord, the vaso-dilators centres are spread throughout the cord. When I destroy the cord below the fifth dorsal vertebra, I cut off vaso-constrictors, the splanchnics, and also annihilate the vaso-dilators, mainly going to the muscles below this point. This section causes a loss of muscular tanos and a great fall of arterial tension. If I destroy the cord about the first or second dorsal, then all the vaso-constrictors are destroyed and nearly all the vaso-dilators. The animals who died seemed to be shocked, probably by the reflex cardiac inhibition and partly by the great vaso-motor paralysis. In cats I made some blood-pressure experiments, and found that the above-mentioned sections and destructions of the cord greatly reduced the blood-pressure. Now, it seems to me, that spinal thermogenic centres play but a small part in the heat production of these experiments. In an animal, after death, I made a transverse section of the whole body at the fifth dorsal vertebra, and the weight of the body anterior to this section was three pounds, while the body weight posterior to the division was a little over five pounds. In this case there could be no spinal thermogenic centres connected with the posterior part of the body, hence we can only have their effect upon the anterior part of the body—that is, the three pounds or three-eighths—while the five-eighths have only the tissue-heat without any nervous action. Now, if we assume for the sake of argument that the heat produced after a section at the fifth dorsal is greatly due to spinal centres, then we must assume that the normal three-eighths of the body can produce as much heat as the normal eight-eighths of the body with an intact nervous system. This, to my view, is an absurdity. It seems to me much more rational to assume that the heat is nearly all produced in the tissues of the body and that the spinal thermogenic centres are of small value. That after the animal is greatly shocked by the section above the fifth dorsal it is easily understood that thermogenesis is greatly arrested. Admitting these facts, it is readily seen that the heat is mainly produced in the tissues, and that the whole nervous system concerned in heat regulation is thermotaxic. If the temperature falls below $98\frac{4}{10}^\circ$ F., then impulses are sent by the cerebral centres to the spinal centres and more heat is generated. If the temperature is above $98\frac{4}{10}^\circ$ F., then the thermo-inhibitory centres of the cortex act or the tuber cinereum may be stirred up, and thermolysis be increased by augmenting the rate of respiration.

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[1] Read before the Physiological Section, Pan-American Congress.

Dr. B. Baculo, of Naples, holds that the thermo-inhibitory centres act directly upon the basal thermogenic. While I have published experiments supporting this view, I think there is little doubt but that they also act directly upon the spinal thermogenic centres.

Dr. E. T. Reichert believes the spinal thermogenic centres to be of a high value, and played upon by cerebral centres, like the heart is played upon by the cerebral nerves. But these experiments show that the cerebral centres are of high value and the spinal thermogenic, *per se*, are of little value.

Dr. Baculo, of Naples, noted an increase of temperature after the injection of an irritant into the corpora quadrigemina. Baculo believes these bodies contain thermogenic centres like the tuber cinereum of the midbrain. The experiments in this paper show that the arterial tension can be greatly lowered and heat production be not affected. In a previous paper I explained this rise of temperature after injury of the corpora quadrigemina as due to lessened tension and changed rate of respiration, but these spinal experiments have changed my mind. What the correct explanation is of this rise after an injury to the corpora quadrigemina remains to be worked out. That the tuber cinereum contains thermogenic centres is shown by the experiment where, with a fine dental drill, I punctured the tuber through the mouth and obtained a temperature of 109° F. It should be remembered that what I have described as the thalamice heat centre and the heat centre about Schiff's expiration crying centre, as well as the thermo-polypnœic centre are all seated in the tuber cinereum. One of the most certain signs that you have punctured the tuber is the accelerated respiration accompanied with a considerable and rapid rise of temperature. In puncturing through the mouth the fibre theory of some writers is demolished, as you injure no fibres in this operation. That transverse sections in front of the caudate nucleus, or of the caudate nucleus itself producing a rise of temperature and increased heat production, will show the presence of heat centres is conceded. But posterior to the corpus striatum no transverse section, even if accompanied with rise of temperature and increased heat production, will localize any heat centre in the pons or medulla, as you have removed part of the heat regulating apparatus anterior to the section and very naturally the temperature rises and heat production is increased. It is only by well localized punctures into grey matter, producing considerable rise of temperature and augmentation of heat production that you can infer the presence of a thermogenic centre at the base of the brain. That injury of the crura will cause a rise of temperature is true, but here you may by puncture injure both thermo-inhibitory and thermogenic fibres, so that no localization of a thermogenic centre can be inferred.

It seems to me that in the cortex the cruciate centre of Eulenberg and Landois, and the Sylvian, are thermo-inhibitory; that the basal thermogenic centres are located (1) in the caudate nucleus, (2) in the grey matter beneath and in front of the corpus striatum, (3) in the tuber cinereum, and that these centres act upon the tissues through spinal centres when the metabolism needs to be accelerated or retarded in activity, to develop the amount of heat necessary to keep the temperature at 98.4° F., and this is an act of thermotaxis. Therefore I believe the function of all these centres, thermogenic and thermolytic, to be heat regulating or thermotaxic.

EXPERIMENT I.—CAT; WEIGHT, 3.34 LBS., SECTION OF CORD AT SEVENTH CERVICAL AND DESTRUCTION BELOW THIS POINT.

	H. P.	H. D.	R. T.	
			Beginning of hour.	Ending of hour.
1st period before section.	30.88	30.34	102.3	102.8
2d “ “ “	22.35	22.35	102.8	102.8
1st period after section.	1.36	19.03	96.6	90.2
2d “ “ “	10.54	13.34	90.2	89.0
3d “ “ “	12.42	12.96	89.0	87.0
4th “ “ “	92.1	11.93	87.0	86.0
5th “ “ “	10.53	13.57	86.0	84.9

EXPERIMENT II.—CAT; WEIGHT, 7.28 LBS.; SECTION OF CORD AT FIFTH DORSAL AND DESTRUCTION OF CORD BELOW THIS POINT.

	H. P.	H. D.	R. T.	
			Beginning of hour.	Ending of hour.
1st period before section.	24.99	27.89	101.1	100.5
2d “ “ “	28.26	32.25	100.5	99.8
1st period after section.	20.56	26.86	99.5	98.4
2d “ “ “	26.44	31.42	98.4	97.5
3d “ “ “	22.38	24.04	97.5	97.2
4th “ “ “	17.03	22.75	97.2	96.2

EXPERIMENT III.—CAT; WEIGHT, 5.52 LBS.; SECTION AT FIFTH DORSAL AND DESTRUCTION OF CORD BELOW THIS POINT.

	H. P.	H. D.	R. T.	
			Beginning of hour.	Ending of hour.
1st period before section.	23.53	26.68	104.6	103.9
2d " " "	23.53	26.68	103.9	103.2
1st period after section.	26.34	32.70	103.0	101.6
2d " " "	32.00	34.73	101.6	101.0
3d " " "	22.33	25.06	101.0	100.4
4th " " "	25.49	24.94	100.4	100.5

EXPERIMENT IV.—CAT; WEIGHT, 4.68 LBS.; SECTION OF CORD AT FIFTH DORSAL AND DESTRUCTION OF CORD BELOW THIS POINT.

	H. P.	H. D.	R. T.	
			Beginning of hour.	Ending of hour.
1st period before section.	27.36	28.81	101.2	101.6
1st " " "	28.90	29.77	101.6	101.4
1st period after section.	24.20	26.10	96.5	96.2
" " " "	25.23	24.46	96.0	96.2
" " " "	20.20	22.85	95.2	95.5
" " " "	24.96	26.80	95.5	95.0
" " " "	24.28	28.29	95.0	94.0